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Quantification of Opencast Potential Within the Waikato Coalfields Using Pit Optimisation Software

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ABSTRACT

Solid Energy New Zealand (SENZ) uses a 20+ year period for integrated planning of all its business activities. It has an ongoing program of coal resource assessment to optimise future mines within this 20 year period, using a six step resource and mine planning process. Desktop review and conceptual study at preliminary Levels 1 and 2 are based on general coal resource information. Further coal resource investigations are carried out for the more detailed evaluations in secondary assessment, prefeasibility study, feasibility study and detailed engineering from Levels 3 to 6.

At Levels 1 and 2, completing conceptual planning, including preliminary resource evaluation and economic appraisal to the target cost uncertainty level of ±33 per cent, is challenging in New Zealand's highly variable geological and geographical conditions. Where coal deposit geometries are relatively simple, approximate methods for determining pit limits using overburden strip ratios, seam thickness, physical boundaries, and quality cut-offs may be sufficient. Many New Zealand coalfields are however complicated structurally, with multiple seams and extensive folding and faulting. Coal seams are characterised by variable dip, thickness, and quality over relatively short distances. In the North Island's Waikato coalfields, coal is typically overlain by weak sediments and clay rich strata that necessitate very flat cut and fill slope angles. The proximity of these deposits to major infrastructure (including towns, highways and rail lines), significant environmental features such as the Waikato river and lakes, and valuable dairy farmland, add further complexity.

Traditional preliminary mine planning techniques applied in these conditions are insufficient. Pit optimisation software, widely used in the metalliferous mining industry since the 1980s, offers the ability to analyse many more specific factors affecting pit limits, mine layouts, and economics, with more rigour and for a much larger number of scenarios, than traditional methods allow. SENZ therefore decided to adapt and use 'Whittle' pit optimisation software for Level 2 analysis of several Waikato opencast prospects. This paper describes this work.

INTRODUCTION

SENZ is New Zealand's leading producer and distributor of high quality coals for export and domestic markets.

SENZ produces over four million tonnes of coal a year from its underground and opencast mines located near Huntly in the Waikato; Greymouth, Westport and Reefton on the West Coast; and Ohai in Southland, as depicted in Figure 1.

More than half of the annual output is metallurgical coal, sold for export for use in steel production as well as the manufacture of carbon fibre, activated carbon and silicon metal.

SENZ's two major domestic customers are the New Zealand Steel Ltd's Glenbrook Steel Mill near Auckland, and the Genesis Energy's Huntly Power Station. SENZ coal also supplies coal to the dairying, cement making, timber and meat processing industries throughout New Zealand.

Background

Demand for SENZ coal within New Zealand has increased in recent years, from 1.6 Mt in 2002, to a forecasted 3.0 Mt for 2005/2006. Over the next ten to 20 years coal-fired electricity plants could be required to provide between 500 and 1000 MW of new generation. This would create an anticipated additional demand for up to 3 Mtpa of coal.

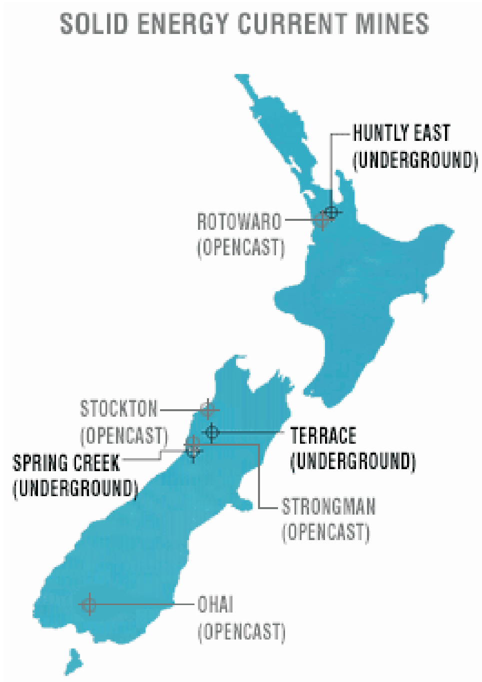

FIG 1 - Location map of SENZ mining operations.

SENZ uses a 20+ year period for integrated planning of all its business activities. It has an ongoing program of coal resource assessment to optimise future mines within this 20 year period, using a six step resource and mine planning process. Desktop review and conceptual study (Levels 1 and 2) are based on general coal resource information. Further geological and coal resource investigations are carried out for the more detailed evaluations in secondary assessment, prefeasibility study, feasibility study and detailed engineering (Levels 3 to 6).

As part of this program SENZ progressed planning for opencast options in the northern Waikato region to Level 2 (conceptual study). This required options to be analysed for a range of mine life – volume – cost scenarios. The complex geology, as well as the large number of potential pit targets and mining scenarios under consideration meant that an efficient method for both pit delineation and financial analysis was essential.

The metalliferous industry has for many years used pit optimisation software based on the Lerchs-Grossman algorithm (Lerchs and Grossman, 1965) to determine optimal pit limits and pit sequencing. Gemcom's Whittle software was identified as the industry standard for pit optimisation, so after ensuring it met SENZ's requirements, was utilised to carry out the task.

Although not commonplace, Whittle software has previously been used for coal applications. In the 1995 'Optimising with Whittle' conference a paper was presented in which Whittle 3D software was used on a complex multi-seam coal deposit in Indonesia (Baafi, Milawarma and Cusak, 1995).

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Current SENZ Waikato operations

Rotowaro opencasts

Rotowaro opencasts are located 10 km southwest of Huntly. Rotowaro coal was first mined in 1915 after a branch railway and a bridge over the Waikato River were completed. Opencast mining commenced in 1958. Currently there are two opencast mines in operation, Township (nearing completion) and Awaroa 4 (under development), producing approximately 1.6 Mt of coal annually. The majority of Rotowaro coal goes by rail to the New Zealand Steel Glenbrook steel mill and to the Genesis Energy Huntly Power Station. The remainder supplies North Island industrial and domestic markets.

At Rotowaro a coal washery and blending plant are used to process and blend coals to optimal product specifications. This enables SENZ to maximise the recovery and market value of its coal reserves.

Huntly East Underground Mine

Huntly East Underground Mine is located immediately north of Huntly township. The mine currently produces approximately 450 kt of coal per annum. Coal is loaded directly onto a branch railway at the mine, which connects to the nearby main trunk line. The majority of East Mine's production is sold to New Zealand Steel's Glenbrook steel mill.

Geology

The Waikato Coal Region consists of coalfields developed 30 - 35 million years ago (the Eocene-Oligocene period). The region extends from Drury (near Auckland) in the north to Mangapehi, south of Te Kuiti.

The Waikato Coal Measures were deposited on an eroded 'basement' of Mesozoic greywackes and argillites. The coal measures are overlain by a succession of marine sediments and an unconformable sequence of much younger sedimentary and volcanic deposits (three million years ago to recent time).

The general structural style is that of block faulting with steeply dipping normal faults.

For each of the Waikato coalfields under investigation, Vulcan grid models for both structure and coal quality existed. In order to utilise Whittle software these geology grid models required conversion to a three-dimensional block model. A common problem when converting grids to a block model occurs where coal and underburden are grouped together within the same block, potentially overstating mining costs for pit optimisation. An in-house SENZ Vulcan macro was written to automate the model conversion, and to address the underburden problem.

Each block within the block model contains the following key information:

- recoverable tonnes and quality (ash, sulfur, specific energy) for each coal seam; and
- volumes and corresponding tonnages for each non-coal stratigraphic unit.

Note that spatial data for each block is inherent within the Vulcan block model framework.

Geotechnical parameters

In general, the stratigraphic horizons present can be consolidated into three geotechnical rocktype categories. Typical overall cut slope angles for each category are listed in Table 1.

TABLE 1

Typical geotechnical parameters by rock type category.

Rock type category	Typical overall cut slope angle	Comments
Basement	60°+	Not generally mined, except where localised faulting disrupts stratigraphic sequence in adjacent blocks.
Coal measures	30 - 40°	Carbonaceous mudstones, shales and coal seams. Relatively competent compared to the overlying unit.
'Softs'	8 - 15°	'Softs' is the colloquial term given to the mechanically incompetent weak rock and soils. In general this applies to all the material above the coal measures.

Mining assumptions

As a first pass for the pit targeting exercise, it was assumed that targets would be large opencast operations, hence bulk earthmoving rates were used to determine the cost structure. Bucket wheel excavators and draglines were ruled out due to the high capital expenditure requirements, plus very weak waste material and unfavourable bedding dips. The mining method and base operating costs assumed were roughly based around the current Awaroa 4 operation, using large truck and shovel fleets (Komatsu PC4000 Excavator and 730E rear dump trucks) for waste.

Identification and evaluation of opencast targets

The process used by SENZ to identify and evaluate opencast potential in the Waikato Coalfields was as follows:

Stage 1 – Run Whittle Pit Shell Generator on coalfield-wide 3D block model

Generic geotechnical parameters were used in Whittle at this stage, differentiated by rock type category. Cut slope angles of 60° for basement, 30° for coal measures and 10° for 'softs' were used.

Bulk earthmoving truck and excavator fleet rates determined the unit cost structure. Coal revenue was defined by the specific energy content of the coal within the block model. A broad range of coal prices was used, from 50 per cent to 200 per cent of the base case revenue.

The potential underburden problem was addressed by converting all material below the target coal seam to air. This ensures that the costs and material quantities calculated during the pit optimisation process are accurate.

For each coal price analysed, Whittle Pit Shell Generator outputs the Lerchs-Grossman optimal pit outlines, and reports the corresponding quantities of coal and waste.

Any pit identified by Whittle at coal prices up to 200 per cent of the base case revenue was highlighted as a potential target area for follow up investigation. Conversely, areas where Whittle failed to identify a pit were eliminated from further consideration.

Stage 2 – Examine target areas

The resultant pit outlines were examined for several reasons:

1. The initial Whittle run was carried out on coalfield-wide models, which covers vast areas. Whittle performs more efficiently on smaller models, hence once target zones have been delineated, block model extents and block dimensions can be adjusted for further Whittle investigation.
2. To ensure that the pit dimensions are consistent with the cost inputs. If bulk earthmoving rates were applied, yet the pit outline infers that smaller mining fleets would be used, then the cost inputs need adjusting accordingly.

3. To determine the location of the pit in relation to surface features. If the pit extends into areas beyond the control of SENZ (for legal, environmental, cultural, or infrastructure reasons), then either the block model requires modifying to identify exclusion zones, or additional costs need to be assigned in Whittle to fully cover the impact of mining (Wharton, 1996).
4. To determine whether the generic coalfield-wide geotechnical cut slope angles used are appropriate for the specific target area.

Stage 3 – Run Whittle Pit Shell Generator on each target area individually

Whittle Pit Shell Generator is run on the target area model, using adjusted geotechnical and cost inputs if required. The resultant pit outlines are re-examined. This is an iterative process, which continues until the assumptions used for the Whittle inputs, and pit outputs are in general agreement.

Stage 4 – Run Mining Scenario

Whittle Mining Scenario is run after defining mining rates, discount rates, and project capital expenditure requirements. A series of pushbacks can be manually or automatically defined within Whittle. Mining can be carried out either to balance quantity schedules or to defer waste, at the user's discretion. For a given coal price, maximum project net present value (NPV) for each pit shell is computed. After validating the resulting Whittle production schedules to ensure mining practicality, coal tonnage and pit NPV data are exported into Microsoft Excel and graphed. The resulting price-tonnage-NPV graphs show the most profitable pit outline for any specific coal price, as well as the sensitivity of the particular target with respect to coal price and pit size.

This completes the Whittle characterisation, and provides extremely useful information for strategic decision-making.

Stage 5 – Detailed project evaluation

Selected Whittle pit shells as identified in Stage 4 are exported into Vulcan and used as the basis for detailed mine design, production scheduling, and financial analysis. By examining the price-tonnage-NPV curves, the mine designer has a good insight into the sensitivity of the pit economics and pit geometry to changes in coal price. Armed with this information, pit designs can to some extent be 'future proofed' to allow for possible expansion or contraction, depending on prevailing economic conditions.

CASE STUDY – KIMIHIA OPENCAST EXPANSION

As part of the Huntly Coalfield regional assessment, the Whittle Pit Shell Generator identified a potential pit target immediately adjacent to the old Kimihia opencast mine.

Background

The existing Kimihia opencast pit was mined from 1944 to 1977. The portals of Huntly East underground mine are located in the western wall of the old pit. Settling ponds and other infrastructure servicing the Huntly East Mine are located within, and adjacent to the former pit. Just prior to the commencement of the Waikato coal targeting exercise, the Kimihia pit area had been the subject of a traditional mine design conceptual study. This was seen as an excellent opportunity to validate and compare the Whittle and traditional process and outputs.

Geology

In the prospect area, the Kupakupa Seam, ranging from 3 to 8 m of coal (excluding partings), is overlain by the Renown seam, ranging from 2 to 4 m of coal (excluding partings), with up to 30 m of interburden between the seams.

The Kimihia target area is typical of the Waikato coalfields, with coal measures overlain by younger sedimentary formations classified as 'softs'. Softs account for approximately half the thickness of non-coal strata within the target area.

The coal in this area consists of multiple split Renown and Kupakupa seams, typically medium ash (~10 per cent) coal with specific energy of 22 Mj/kg (as received basis), and total sulfur of 0.3 per cent.

Geotechnical

The pit design parameters used for the Whittle Pit Shell Generator were modified from the generic Waikato-wide cut slope angles to account for local conditions. Overall slope angles of 60° for basement, 34° for coal measures, and 11° for 'softs' were chosen.

Mining

The coal quality within the target area meant that Kimihia coal would require blending with other coal sources. For the purpose of this study, it was assumed that the coal production from the target area was limited to 500 kt per annum.

The characteristics and size of the target meant that waste removal by truck/shovel operation using Komatsu PC4000 excavators with Komastu 730E trucks, or equivalent was considered appropriate.

Two methods of coal winning were assessed:

1. bulk winning of coal and included partings, followed by processing in a dense medium washery; or
2. selective coal winning using 45 tonne excavators on dayshift only, in order to minimise contamination during selective mining of thin coal seams.

The selective option was favoured after economic analysis showed the costs of a dense medium plant to be prohibitive, hence coal mining costs for Whittle optimisation were based on selective mining using 45 t excavators with 40 t trucks.

Surface features

Within the Kimihia target area there exist a number of infrastructure and other surface features, including public roads, Huntly East Mine site infrastructure and underground access roadways. In addition, a proposed diversion of State Highway One in the northeast of the target area is scheduled for construction by 2020.

Due to the large number of surface features, two separate scenarios were considered. Firstly the model was constrained to avoid all surface infrastructure, however constraining the Whittle Pit Shell Generator in this manner meant that no economic pit could be found.

The second scenario did not constrain the Whittle Pit Shell Generator in any way, however the additional costs associated with relocating or replacing each surface feature were built in to the model to reflect the associated financial implications.

Whittle outputs

The Whittle Pit Shell Generator was re-run using the revised Kimihia-specific parameters. Next, the Whittle Mining Scenario program was run to produce mine schedules that maximise project NPV based on 500 kt per annum coal production, while balancing annual waste production, for a specified range of coal prices.

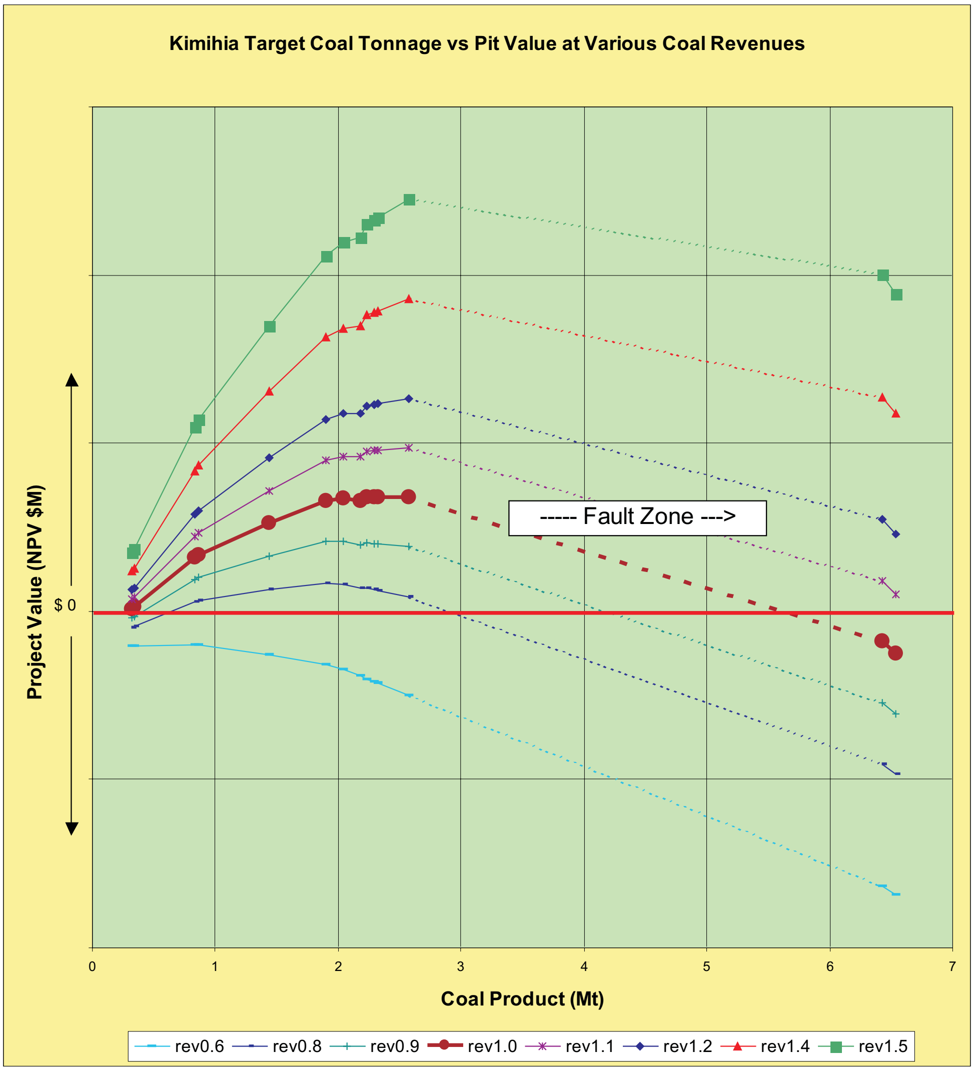

FIG 2 - Graphical representation of Kimihia Whittle output (modified).

Whittle Mining Scenario results were exported into Microsoft Excel, and subsequently graphed. Figure 2 shows an example of the graph obtained from this process. Note that the results shown within this paper have been modified to protect commercially sensitive information.

The base case revenue curve (rev1.0), represented in Figure 2 shows a positive project NPV for pit sizes up to and including approximately 2.6 Mt, with a maximum NPV achieved at approximately 2.4 Mt. Note that for the range of pit sizes from approximately 1.9 - 2.6 Mt there is very little change in project NPV. This infers that when the detailed pit design is undertaken, minor deviations from the optimal Whittle pit outline will not cause a significant change in project economics.

At coal prices ten per cent greater than the base case (represented by the rev1.1 curve), Figure 2 indicates that the project economics could support a larger pit, up to 6.5 Mt and achieve a positive NPV. Note that the dashed lines between the 2.6 Mt and 6.4 Mt pits represents a significant jump in pit size, and is due to a down thrown faulted block of coal.

In this specific example, if maximising project NPV is the company objective, there is no point in chasing the larger pit options, as under all scenarios the highest project NPV is achieved at pit sizes of 2.6 Mt or less.

If the 2.4 Mt pit option is chosen, representing the maximum project NPV for the base case coal price, it can also be seen that in the event of coal prices dropping 20 per cent (represented by the rev0.8 curve), the project still achieves a positive NPV. If the coal price drops 40 per cent below the base case (represented by the rev0.6 curve), then the project never achieves a positive NPV under any pit size.

In order to 'future-proof' the pit project, the mine designer would be wise to avoid sterilising the coal between the 2.4 Mt and 2.6 Mt pit options, as there is some potential upside in the event that the coal price increases above the base case during the project life. There is no benefit in avoiding sterilisation of the coal beyond the 2.6 Mt pit limits, unless practicable to do so without incurring additional mining costs, as under no scenario does the larger pit option appear financially attractive compared to the smaller pit options.

All this is extremely valuable information to have at the time of mine design and initial project assessment.

Whittle versus traditional method

Prior to using Whittle, the preferred mining scenario for Kimihia, as determined by traditional methods, was a pit containing 2.4 Mt of mineable coal. A number of pit options, using vertical strip ratio and surface constraints as a guide, were designed in Vulcan and analysed individually before determining the preferred scenario.

Using Whittle, numerous mining scenarios were examined, in which costs, cut slope angles, production rates, coal prices, and exclusion zones were varied. The entire process only took two days. The resulting preferred Whittle pit option also contained 2.4 Mt of mineable coal, however it did so with significantly less overburden material than the traditional pit, and hence achieved a more favourable financial outcome.

The results achieved using Whittle on the Kimihia target area validated the methodology, as well as giving credibility to its use within SENZ. The high level of structural complexity at Kimihia resulted in the Whittle method outperforming the traditional mine design method, and doing so in a fraction of the time.

Future work

Results from the Whittle targeting exercise have shown a potential economic target, albeit a fairly small tonnage project, in the Kimihia region of Huntly coalfield.

Limitations in the geological model for the Kimihia target area have been identified, and a resource definition drilling program has commenced. A more extensive Whittle investigation will take place once the updated geological model is available, before progressing the project to a full pre-feasibility study.

CONCLUDING REMARKS

Use of Whittle pit optimisation software for evaluation of opencast options in the Waikato coalfields has set a new benchmark for SENZ project assessment methodology for geologically complex resources at Conceptual Study stage. SENZ opencast projects are now being routinely analysed using Whittle as part of the strategic mine planning process.

REFERENCES

Baafi, E Y, Milawarma, E and Cusak, C, 1995. Application of Whittle 3D pit optimizer to a multi-seam coal deposit, in *Optimising with Whittle*, pp 13-21 (Whittle Programming Pty Ltd: Perth).

Lerchs, H and Grossman, I F, 1965. Optimum design of open pit mines, *Transactions Canadian Institute of Mining and Metallurgy*, 68:17-24.

Wharton, C L, 1996. What they don't teach you in mining school – tips and tricks with pit optimisers, in *Surface Mining 1996*, pp 17-22 (South African Institute of Mining and Metallurgy: Johannesburg).